Miniature Lightweight X-ray Optics for Solar System Exploration

Completed Technology Project (2016 - 2019)

Project Introduction

X-ray observations of planetary objects provide a unique window on fundamental processes associated with the formation and evolution of individual bodies and the Solar System as a whole. Future X-ray observations for planetary science require a sensitive yet compact X-ray imaging spectrometer that can operate in in-situ missions. The proposed new type of Miniature X-ray Optics (MiXO) can finally bring highly successful Wolter-I X-ray optics to planetary science within affordable mass, power, and cost constraints. The elemental composition of planetary bodies is of fundamental interest to planetary science and to understanding the origin, evolution and future of life in the Solar System. X-ray fluorescence, induced either by solar X-ray flux or impacting energetic ions, carries a decisive signature of surface elemental composition. X-ray observations in the 0.1-15 keV band are a unique, powerful diagnostic tool since they cover K or L-shell fluorescence lines from all but three elements, from life essential light elements to rare earth heavy elements. X-rays from solar wind charge exchange enable probes of the dynamic and energetic interaction between comets, planetary exospheres and the influence of solar wind plasma upon planetary surfaces. The proposed optics offer flexible and affordable observing opportunities and enable efficient X-ray telescope configurations that can identify the elemental composition of a wide range of planetary bodies from asteroids and comet nuclei to airless planets and satellites. High resolution imaging with MiXO can not only identify small regions with abundant organic or unusual elements but will also allow straightforward comparison between the elemental distribution and the surface topology, which can reveal the system's evolutionary and geological history such as crater-induced sub-surface grain exposure or localized volatile depletion. As X-rays are emitted from the planetary bodies through a variety of other physical processes, applications of the proposed technology reach far beyond the study of elemental composition. This program proposes to build three prototype MiXO modules, bringing the technology from TRL 2 to 4 by its end. MiXO inherits the progress in electroformed Nickel replicated (ENR) Wolter-I optics in the past two decades and utilizes new metal/ceramic hybrid technology using Plasma Thermal Spray (PTS) to achieve lightweight X-ray optics. Its efficient light collecting capability exceeds the performance of alternative approaches in planetary science such as micro-pore optics (MPO) by a large factor (>~3). In addition, MiXO enables high angular resolution (<30 arcsec) over a wide field of view (>1 deg), improving the detection sensitivity of surface features by an order of magnitude relative to MPO. MiXO also extends X-ray imaging to higher energies (up to ~15 keV) for detection and mapping of heavy elements. The modular design of MiXO can be easily scaled from low-cost Explorer-class to small Discovery or medium class New Frontiers missions. For Flagship missions, the proposed technology will open a door for powerful, cost-effective X-ray optics that are sensitive enough to distinguish between different organic species and thus detect astrobiological evidence in Europa. The experts in X-ray optics and telescope systems, who have been the force behind the advances in ENR

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Organizational Responsibility

Responsible Mission Directorate:

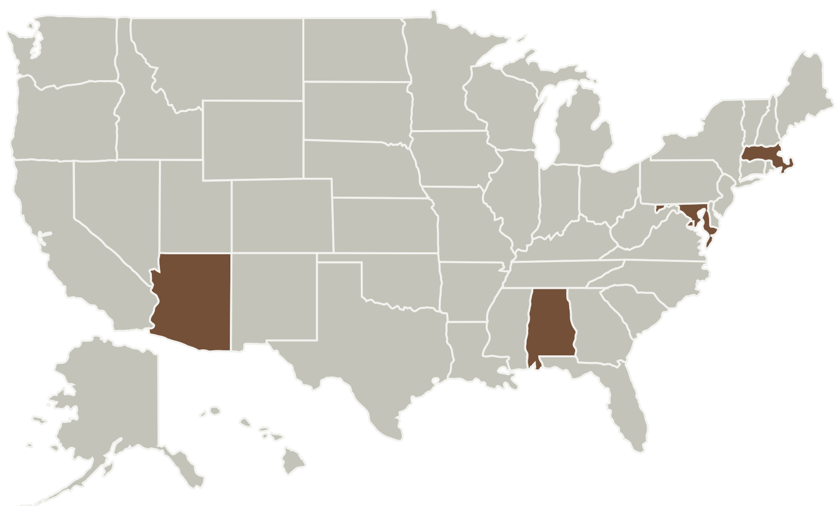
Science Mission Directorate (SMD)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

X-ray optics technology, will lead the technical efforts. The prominent planetary scientists and astrophysicists will also join the efforts to guide the MiXO design optimization for planetary science. The proposed three year plan will not only demonstrate the technical feasibility and advantage of MiXO by building progressively higher performance prototypes of MiXO, but it will also enable several MiXO designs that can be readily adopted in a wide range of future planetary missions. MiXO will make a quantum leap in realizing the full potential of future planetary X-ray observations.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Harvard University	Supporting Organization	Academia	Petersham, Massachusetts

Primary U.S. Work Locations	
Alabama	Arizona
District of Columbia	Maryland
Massachusetts	

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

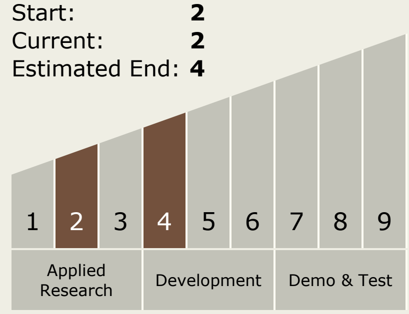
Jonathan E Grindlay

Co-Investigators:

Martin Elvis
Larry R Nittler
Marrybell Ramos
Suzanne E Romaine
Graziella Branduardi-raymont
Almus Kenter
Scott J Wolk
Carey M Lisse
Jae Sub Hong
Brian D Ramsey
Lucy F Lim
William V Boynton
Richard Binzel
Ralph Kraft

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └─ TX08.1 Remote Sensing Instruments/Sensors
    └─ TX08.1.1 Detectors and Focal Planes

Target Destination

Others Inside the Solar System